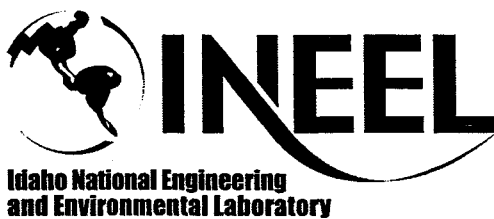


# **Engineering Design File**

## **Liner/Leachate Compatibility Study**



1. Title: Liner/Leachate Compatibility Study				
2. Project File No.: NA				
3. Site Area and Building No.: NA			4. SSC Identification/Equipment Tag No.: NA	
5. Summary: This study evaluates the compatibility of the liner materials with the leachate generated by the waste disposed in the INEEL CERCLA Disposal Facility. The liner system is composed of both natural and synthetic materials including compacted clay, geosynthetic clay liner, high-density polyethylene, and polypropylene products. This study will determine whether these materials are compatible with the leachate, based on experience at similar landfills and published literature.				
6. Review (R) and Approval (A) and Acceptance (Ac) Signatures: (See instructions for definitions of terms and significance of signatures.)				
	R/A	Typed Name/Organization	Signature	Date
Performer		Phillip Crouse/ Montgomery Watson	<i>Phillip E. Crouse</i>	05/14/02
Checker	R	(Same as Independent Peer Reviewer)		05/14/02
Independent Peer Reviewer	A	Marty Doornbos/ BBWI	<i>Marty Doornbos</i>	05/14/02
Approver	A	Thomas Borschel/ BBWI	<i>Thomas F. Borschel</i>	05/14/02
Requestor	Ac	Don Vernon/ BBWI	<i>D. Vernon</i>	05/14/02
7. Distribution: (Name and Mail Stop)		M. Doornbos, MS 3930; D. Vernon, MS 3930; T. Borschel, MS 3930		
8. Records Management Uniform File Code (UFC):				
Disposition Authority:			Retention Period:	
EDF pertains to NRC licensed facility or INEEL SNF program?: <input type="checkbox"/> Yes <input type="checkbox"/> No				
9. Registered Professional Engineer's Stamp (if required)				

## **ABSTRACT**

This study evaluates the compatibility of the liner materials with the leachate generated by the waste disposed in the INEEL CERCLA Disposal Facility. The liner system is composed of both natural and synthetic materials including compacted clay, geosynthetic clay liner, high-density polyethylene, and polypropylene products. This study will determine whether these materials are compatible with the leachate, based on experience at similar landfills and published literature.



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## ACRONYMS

ASTM	American Society for Testing and Material
CCL	compacted clay liner
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CETCO	Colloid Environmental Technologies Company American
EDF	engineering design file
EPA	Environmental Protection Agency
GCL	geosynthetic clay liner
HDPE	high-density polyethylene
ICDF	INEEL CERCLA Disposal Facility
INEEL	Idaho National Engineering and Environmental Laboratory
LERF	Liquid Effluent Retention Facility
PCB	polychlorinated biphenyl
RCRA	Resource Conservation and Recovery Act
SBL	soil bentonite liner
TCE	trichloroethylene
TSCA	Toxic Substances Control Act
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WAC	Waste Acceptance Criteria





# **Liner/Leachate Compatibility Study**

## **1. INTRODUCTION**

### **1.1 Purpose**

The purpose of this study is to demonstrate that the liner materials proposed for the INEEL CERCLA Disposal Facility (ICDF) landfill and evaporation pond are chemically compatible with the leachate. Certain materials deteriorate over time when exposed to chemicals that may be contained in hazardous leachate. It is important to anticipate the type and quality of the leachate that the landfill will generate and select compatible liner materials. Data collected from other similar low-level radioactive mixed waste and hazardous waste sites was used to determine the allowable concentration of leachate constituents that could be in contact with the ICDF landfill and evaporation pond liner components.

### **1.2 ICDF Liner System**

The ICDF landfill and evaporation pond liners are a double composite system compliant with the substantive requirements of the Resource Conservation and Recovery Act (RCRA) Subtitle C and the Toxic Substances Control Act (TSCA) polychlorinated biphenyl (PCB) landfill and surface impoundment design, consisting of leachate collection/detection systems, a 3-ft-thick soil bentonite liner (SBL) (landfill only), and flexible membrane liners. The specific liner materials are listed below:

- High-density polyethylene (HDPE) geomembranes
- Geosynthetic clay liner (GCL) consisting of a thin layer of bentonite sandwiched between two synthetic geotextiles
- Geocomposite consisting of a HDPE geonet and geotextile
- Compacted clay soil with a bentonite admix (soil bentonite layer [SBL]) to decrease permeability.

The evaporation pond liner also includes an additional sacrificial geomembrane for UV protection.

In general, the liner system consists of two types of materials. The geomembranes, geotextiles, and geonets are manufactured from polymeric materials made from synthetic polymers. HDPE products have a high crystallinity that increases the chemical resistance of the polymer. The second type of material is soil comprised mainly of clay-sized particles, also crystalline in nature. As part of this study, no information was found with respect to the degradation of the geotextile materials. It was determined that even if the geotextile materials used in the liner system degraded, that it would not negatively impact the containment qualities of the landfill. Therefore, the degradation of geotextile was not considered as part of this study.

### **1.3 Mechanisms of Liner System Deterioration**

Specific mechanisms of deterioration of the liner system components that might be encountered based on the waste inventory are chemical, radioactive, and oxidation degradation. Degradation involves a change in the physical properties of the liner material that could increase the permeability of the material or reduce the material's strength or ductility.

Polymeric chain scission or bond breaking within the polymer structure of HDPE results in degradation. Chemical degradation for HDPE products is a concern for leachates containing high concentrations of organic solvents or other highly reactive chemicals. High radiation doses also have the potential to cause chain scission in polymers. Oxidation occurs when free radicals and oxygen are present and results in chain scission. Oxidation processes are slowed considerably in liquid environments and antioxidant formulations are added to most HDPE products (Koerner 1998). Oxidation is also significantly reduced when the liner system is buried. As discussed herein, these processes are not expected to occur based on the ICDF leachate quality.

HDPE geomembranes can deteriorate from contact with certain leachates, resulting in a decrease of elongation at failure, an increase in modulus of elasticity, a decrease in the stress at failure, and a loss of ductility. Similarly, the permeability of a SBL and GCL can increase or decrease due to certain constituents in the leachate. This study is intended to establish individual leachate constituent concentration limits that will not adversely impact the liner system components. A summary of the properties for the HDPE, SBL, and GCL liner materials and the effects that could result from exposure to an aggressive leachate are summarized in Table 1-1. Notably, aggressive leachate in the ICDF landfill or waste liquid in the evaporation pond are not anticipated during their service life.

Table 1-1. Potential effects of aggressive leachate on liner materials.

Liner Material	Property	Typical Value	Possible Effect of Leachate
60 mil Textured HDPE	Thickness	> 60 mils	Decrease
	Melt Index	< 1.0 g/10 min	Increase or Decrease
	Strength at yield	> 120 lb/in.	Increase or Decrease
	Strength at break	> 75 lb/in.	Increase or Decrease
	Elongation at yield	> 12%	Increase or Decrease
	Elongation at break	> 100%	Increase or Decrease
	Tear Resistance	> 42 lb	Increase or Decrease
	Puncture Resistance	> 80 lb	Increase or Decrease
	Environmental Stress Crack	> 200 hours	Increase or Decrease
SBL	Permeability	< $10^{-7}$ cm/sec	Increase or Decrease
GCL	Permeability	< $10^{-7}$ cm/sec	Increase or Decrease

Sodium bentonite is the primary clay mineral in SBLs and GCLs that results in a low permeability and high swell potential. Exposure of sodium bentonite to liquids containing concentrated salts (such as brines), or divalent cation concentrations (such as  $\text{Ca}^{++}$  and  $\text{Mg}^{++}$ ), reduces the swelling potential and increases its permeability. Concentrated organic solutions (such as hydrocarbons) and strong acids and bases can break down the soil, which also increases permeability. The physical mechanism that causes these changes is a reduction of the thickness or absorption capacity of the diffuse double layer of water molecules surrounding the clay minerals. This results in an effective decrease in the volume of the clay since the water molecules are not attracted to the clay particles.

## 1.4 ICDF Leachate Concentrations

Soluble contaminants leached from the waste will come in contact with the landfill and evaporation pond bottom liner system during the operation period (15 years) and minimum post closure period

(30 years). The natural soil bentonite liner system may be in contact with soluble contaminants as long as contaminants are present in the landfill. The synthetic liner system components may be in contact with soluble contaminants until they naturally degrade or become ineffective. Leachate is generated from water added to the waste for dust control and compaction purposes. Natural precipitation events also contribute to leachate production. In reality, as the landfill nears the end of its operational life, concentrations of contaminants will decrease with time as the leachable waste mass is reduced. During the post-closure period, a robust landfill cover will significantly reduce infiltration, and the corresponding volume of leachate.

An inventory of constituents and associated site-specific concentrations anticipated in the waste are published in the INEEL CERCLA Disposal Facility Design Inventory (EDF-ER-264). The expected chemical make-up of the leachate was determined based on modeling described in the leachate/contaminant reduction time study (EDF-ER-274).

Two hydrogeologic models were used to simulate leachate generation during the operational period (15 years) and post-closure period (30 years) of the ICDP landfill and evaporation pond. The post-closure period includes the waste-filled landfill having a cover to reduce infiltration and the generation of leachate. The models applied partitioning coefficients to the waste design inventory mass to determine a liquid concentration for each constituent, and resulting leachate concentration.

In addition to the hydrogeologic models, a geochemical evaluation was performed for the operational period to evaluate natural geochemical reactions that could potentially generate constituents harmful to the liner system materials in the landfill or evaporation pond other than by the soluble waste constituents alone. It also was used to determine the general composition of the leachate including pH. The geochemical evaluation consisted of determining the chemistry make-up of the leachate based on the constituents in the waste soil and the geochemical reactions between the atmospheric gases (i.e., O<sub>2</sub>, CO<sub>2</sub>, etc.), infiltrating water, and natural occurring minerals in the soil.

The maximum and average leachate concentrations determined from the operational 15-year and post-closure 30-year hydrogeologic models were compared to determine the worst-case leachate concentrations due to the contaminants in the waste soil. Based on the comparison, the highest concentration of contaminants would occur during the operational period since contaminant transport tends to be dominated by drainage and diffusion, driven by the infiltration rate, which is expected to be small once the landfill is covered (EDF-ER-279).

Based on the geochemistry evaluation, the modeled leachate composition will be a brackish water with a pH of 8.0 (EDF-ER-274). Some of the constituents in the leachate had higher concentrations than determined by the hydrogeologic model due to the added effects of geochemical reactions. These mainly included sodium and sulfate having concentrations of approximately 8,000 and 20,000 mg/L, respectively. Brackish solutions containing high-concentration divalent cation concentrations such as calcium and magnesium can increase the permeability of the SBL and GCL liner materials as discussed in Section 1.3. The predicted divalent cation (calcium, magnesium, manganese, and barium) total concentration is approximately 400 mg/L. Higher concentrations are predicted from the 15-year hydrogeologic model of approximately 4,000 mg/L due to more conservative assumptions than the geochemical model. In either case, the divalent cation concentration is less than the maximum allowable concentration of 35,000 mg/L for the SBL and GCL described in Section 3.

Based on the 15-year hydrogeologic model, the maximum leachate concentration occurs during the first year of operation. The maximum and average concentrations for organics, inorganics, and radionuclides are provided in Table 1-2. These concentrations are considered conservative since they

were determined assuming that the entire landfill is filled with waste instantaneously and has a constant moisture content of 6% by dry weight for all 15 years of operation.

Table 1-2. Maximum and average concentrations of leachate constituents by chemical category.

Chemical Category	Maximum Concentration	Average Concentration
Organics	70 mg/L	10 mg/L
Inorganics	18,400 mg/L	17,100 mg/L
Radionuclides	1 mg/L (0.00002 Ci/l)	1 mg/L (0.00001 Ci/l)

The resulting constituents determined from the leachate/contaminant reduction time study are provided in Appendix A. The organic constituents and expected concentrations are provided in Table A-1. The inorganic constituents and expected concentrations are provided in Table A-2. The expected radionuclides and activity concentrations are provided in Table A-3.

## 1.5 Absorbed Dose In Geomembrane

Studies performed on polymer materials like HDPE show that their properties begin to change after absorbing ionizing radiation between 1,000,000 to 10,000,000 rads (Koerner et al. 1990). The HDPE geomembrane lining the bottom of the landfill and evaporation pond will absorb ionizing radiation energy from the leachate generated in the landfill and combination of leachate and other waste liquids in the evaporation pond. Energy will be absorbed during the operational life of the landfill and evaporation pond as long as there are liquids with ionizing radionuclides in contact with the geomembranes.

The absorbed dose in the geomembrane was determined by multiplying the dose rate by an absorption duration. Conservatively, the absorption duration was assumed that the leachate was in contact continuously with the liner for the entire 15-year landfill operational life. In reality, leachate will be in contact with the landfill geomembrane intermittently depending on climatological and waste moisture content conditions. The absorption duration in the evaporation pond will be shortlived, due to evaporation and dilution from make-up water.

A design absorption rate was calculated for each of the radionuclides listed in Appendix A, Table A-3. Exceptions included Krypton (Kr-85 and Kr-81), which is a gaseous element, and radionuclides that are not in the leachate. The design absorption rate is dependent upon the physical properties of the absorbing material and how the energy from the source is deposited into the material. The physical properties of the HDPE geomembrane needed to determine the absorption rate are provided in Table 1-3.

Table 1-3. Physical properties of geomembranes.

Parameter	Value	Units
HDPE density	0.94	g/cm <sup>3</sup>
Geomembrane thickness	1.5	mm
Unit surface area	1	cm <sup>2</sup>

The amount of energy was based on the depth of leachate on the landfill liner and depth of liquids in the evaporation pond. The maximum depth of leachate was estimated as 4 cm across the floor of the landfill, assuming both Cell 1 and Cell 2 are in operation (EDF-ER-269). In the sump area of the landfill, the maximum leachate head would be approximately 30.5 cm. If the volume of leachate 4 cm deep over

the area of the landfill (Cell 1 and Cell 2) was placed in the evaporation pond, the depth of leachate in the evaporation pond would be approximately 36 cm. Using these depths, the activity concentration, and the geomembrane properties, the design absorption rate was computed for each radionuclide. The computation is provided in Appendix B. The design absorption rates are listed in Table A-4, provided in Appendix A.

The design absorbed dose to the geomembrane is approximately 0.09 and 0.8 rads per hour, for the landfill and evaporation pond, respectively. Assuming the leachate concentration and composition remains constant, the total doses over the 15-year operation life are conservatively estimated to be 12,000 and 100,000 rads for the landfill and evaporation pond, respectively. The total dose for the landfill for 1000 years is estimated to be 800,000 rads. This assumes that all the energy from the leachate will be absorbed in the geomembranes. In reality, only small fractions of alpha and beta particles will penetrate the geomembrane material. Notably, the upper sacrificial geomembrane lining the evaporation ponds will absorb the majority of the ionizing radiation with little dose to the underlying primary geomembrane. Based on radiation absorbed dose, the mechanical properties of the HDPE liner are not expected to be degraded below acceptable levels.

## **2. EXISTING STUDIES OF LINER/LEACHATE COMPATIBILITY**

### **2.1 EPA Method 9090**

In 1992, EPA published Method 9090, 'Compatibility Tests for Wastes and Membrane Liners,' to set the standard that liners must meet to be protective of human health and the environment. This test has been used throughout the industry to demonstrate that liners are compatible with numerous leachate compositions from municipal and hazardous waste landfills, and surface impoundments. The results of these studies have been documented and are readily available. The manufacturers of the liners now supply limitations of the products based on these tests. The results are commonly accepted as reliable and complete. Since the ICDF leachate contains no unusual or excessive constituents, the industry results for these liners is sufficient to demonstrate compatibility.

The compatibility of GCL and SBL materials are usually demonstrated by permeating the material with leachate to determine its permeability. Method 9090 consists of immersing small sample specimens of a liner material in leachate and periodically measuring changes in the physical properties. The specimens are removed after 30, 60, 90, and 120 days, then tested to determine changes to the physical dimensions and mechanical properties. Acceptance criteria for defining compatibility tend to vary. Compatibility has been defined as geomembrane properties remaining above the minimum suggested property value or an allowable small percentage of change in properties (e.g., less than 15%) to maintain the integrity of the liner.

GCL and SBL are tested for compatibility by permeating the material with a leachate solution to determine effects on the hydraulic performance of the material. Typically, solutions with high concentrations of contaminants or pure products are allowed to permeate a sample under confining pressure to determine the saturated permeability of the material using ASTM methods such as ASTM D5084. A saturated permeability exceeding  $1 \times 10^{-7}$  cm/sec would indicate incompatibility.

The HDPE geomembrane and GCL materials planned for the ICDF are considered to be the most chemically inert liner materials commercially available for waste disposal facilities. Numerous studies using EPA Method 9090 and permeability tests, among other testing procedures, have been performed for waste disposal facilities and in the laboratory providing a good understanding of the compatibility behavior of these liner materials.

### **2.2 Published Studies**

#### **2.2.1 Comparison with Other Geomembrane 9090 Compatibility Studies**

Relevant compatibility studies have been performed at DOE's Hanford facility near Richland, Washington. These projects include the Liquid Effluent Retention Facility (LERF), W-025 landfill, and the Grout Facility. Other relevant studies include the Kettleman Hills landfill located in northern California. The results of these published studies indicate that a HDPE geomembrane will function well as a liner beneath the landfill waste or liquid waste in the evaporation pond. The published geomembrane compatibility studies for the Hanford facility are listed in Section 6 Bibliography of this report.

A comparison between the anticipated ICDF landfill leachate and that used in compatibility tests for other facilities is summarized in Table 2-1.

Table 2-1. EPA test method 9090 compatibility studies comparison.

Compatibility Study <sup>a</sup>	Type of Material Tested	General Composition of Leachate	9090 <sup>b</sup> Test Concentrations or Radiation Exposure that Demonstrated Compatibility in Each Study	ICDF <sup>c</sup> Leachate Concentration/Absorbed Radiation
Hanford LERF	60-mil smooth HDPE from four manufacturers	Organics	16.25 mg/L	70 mg/L
Hanford W-025 Landfill	60-mil smooth HDPE	Inorganics	204,210 mg/L	18,400 <sup>g</sup> mg/L
		Organic Leachate and Radiation Exposure	50,000 rads	12,000 rads (landfill)
				100,000 rads (evaporation pond)
Hanford Grout Facility	60-mil smooth HDPE	pH	9.2	8.0
		Inorganics	368,336 mg/L	18,400 mg/L
		Organic Leachate and Radiation <sup>e</sup> Exposure	37,000,000 rads	
		Organic Leachate and Radiation <sup>f</sup> Exposure	16,000,000 rads	12,000 rads (landfill)
				100,000 rads (evaporation pond)
Kettleman Hills Landfills	60-mil smooth HDPE	pH	>14	8.0
		Organics	93,040 mg/L	70 mg/L
		Inorganics	250,000 mg/L	18,400 mg/L
Unidentified Landfill Study	Textured HDPE	pH	>12	8.0
		Organics	154 mg/L	70 mg/L

a. Detailed compatibility test information is provided in *Evaluation of Liner/Leachate Chemical Compatibility for the Environmental Restoration Disposal Facility report* (USACE 1995).

b. EPA Test Method 9090 "Compatibility Test for Wastes and Membrane Liners" (EPA 1992).

c. Values reported represent values at which the test was run, showing no unacceptable effects. They do not represent an allowable limit.

d. Values based on the "Leachate/Contaminate Reduction Time Study" (EDF-ER-274).

e. A slight reduction in strength and elasticity of the HDPE liner occurred at the highest doses used in the testing.

f. No measurable changes in the HDPE liner material properties were observed after the testing.

g. Reported as total inorganics.

HDPE is chemically resistant to inorganic salt solutions and can be incompatible with some organic solutions at high concentrations (i.e., pure products). Actual compatibility tests from other landfills show that HDPE is chemically resistant to much higher concentrations of organics in the leachate than what is expected in the ICDF leachate. The organic concentration in the Kettleman Hills Landfill leachate is almost four orders of magnitude higher than what is expected in the ICDF landfill leachate. The use of general categories of chemicals rather than individual constituents has been accepted by the EPA for the Environmental Restoration Disposal Facility at Hanford and provide a worst-case scenario due to possible synergistic effects of mixed compounds.

The EPA Method 9090 tests performed on HDPE geomembrane liner planned for the Grout Facility included high temperatures and doses of large amounts of radiation. The leachate solution temperature was increased to 194°F, which is significantly above the standard test temperatures of 73° and 122°F required in Method 9090. Additionally, the samples were irradiated at doses up to 37,000,000 rads prior to the testing, significantly decreasing the strength and elasticity (i.e., greater than 25%) of the geomembrane specimens (USACE 1995). Geomembrane samples tested for the W-025 facility did not produce measurable changes in the HDPE liner properties when irradiated for 120 days with a total dose of 50,000 rads. HDPE geomembranes are manufactured with additives to improve ductility and durability such as carbon black and antioxidants. The literature also indicates that these additives allow higher doses than standard HDPE material alone (Kircher and Bowman 1964). The literature indicates that thin films (i.e., 0.002 in.) of different types of HDPE material alone can become brittle when irradiated at doses between 4,400,000 and 78,000,000 rads. Studies performed using polymer materials show that properties typically begin to change at a total radiation dose of between 1,000,000 and 10,000,000 rads (Koerner et al. 1990).

The landfill and evaporation pond HDPE geomembrane liners are expected to receive a dose from the leachate of 12,000 and 100,000 rads, respectively. This is a conservatively high dose since it assumes that concentrations of radionuclides are constant in the leachate over the 15-year operational life of the landfill. Even though conservatively high, the total dose is below the dose found in other studies (i.e., 1,000,000 rads) that may affect the properties of the geomembrane.

## **2.2.2 Geosynthetic Clay and Soil Bentonite Liners**

Based on review of the published studies listed in Section 6 (Bibliography), SBL and GCL perform well unless exposed to high concentrations of divalent cations, very acidic or basic solutions, or solutions with a low dielectric constant (such as gasoline). The leachate expected at the ICDF will have a pH of 8, slightly above neutral. The studies further demonstrate that, when confined, as is the case in the ICDF landfill, or pre-hydrated, SBLs and GCLs will perform well when exposed to high divalent cation concentrations.

Several studies were found that evaluated the impact of SBL permeability with various organic and inorganic materials. The majority of them used very concentrated compounds, which is not the typical composition of landfill leachates and when compared with ICDF leachate exceeded concentrations by as much as an order of magnitude. One study was found that addressed the issue of when leachate constituent concentrations impact SBL permeability. For this study, four different types of organic compounds were used as permeants. They included methanol, acetic acid, heptane, and trichloroethylene (TCE). The results indicate that soil permeability was not affected by methanol until a concentration of 80% by volume was used. The acetic acid actually reduced the soil permeability due to dissolution and reprecipitation of the soil. Heptane and TCE had no effect on permeability when used up to their solubility limit in water. However, when used in pure form, they increased the soil permeability significantly (250 to 1,000 times). In addition to the concentration of the permeant used, changes in hydraulic permeability are also governed by the mineralogy of the soil (Borders 1986). Although only low



concentrations of TCE are predicted in the ICDF leachate, the study demonstrates that high concentrations of organic constituents are required to affect permeability.

No studies were identified that considered the long-term effects of radiation on the physical properties of the SBL or GCL materials. Since long-term studies cannot be conducted, conservative radiation limitations have been employed. Low-permeability soils have been used at multiple DOE facilities containing radioactive waste. The only potential adverse reaction that could occur with the SBL or GCL would be high heat that could dry out these materials, however, it is anticipated that the radioactive material placed in the ICDF will not generate any thermal gradients across the liner system.

The concentration of organic material is expected to be approximately 70 mg/L. This is significantly below the concentration of a highly concentrated solution so it will not increase the permeability of the SBL and GCL. The amount of radioactivity will be low in the ICDF landfill waste and will not generate a significant amount of heat that can desiccate the compacted clay. Additionally, the operations layer will provide a 3-ft buffer between the liner system and waste.

## **2.3 Manufacturers' Data**

### **2.3.1 HDPE Geomembrane**

The manufacturers of the geosynthetic products proposed for the ICDF landfill have published maximum allowable concentrations of various chemical compounds that can contact the HDPE geomembrane without adversely affecting its performance. The most recent recommended maximum concentrations of chemicals were obtained from the manufacturer. A list of the manufacturers' maximum allowable concentrations for specific leachate constituents on HDPE material is provided in Appendix C. In addition, the effects of radiation exposure with respect to the geomembrane physical properties are also presented.

### **2.3.2 Geosynthetic Clay and SBLs**

The GCL underlying the geomembrane in the ICDF landfill and evaporation pond liner consists of processed sodium bentonite clay sandwiched between two geotextile fabrics. The SBL underlying the geosynthetic liners also consists of 5% by weight of processed bentonite amendment. Sodium bentonite is an ore comprised mainly of the montmorillonite clay mineral with broad, flat, negatively charged platelets that attract water hydrating the bentonite. The swelling provides the ability to seal around penetrations, giving the GCL its self-healing properties. A GCL product with Volclay® type sodium bentonite manufactured by CETCO will be installed in the landfill and evaporation pond.

The GCL manufacturer allows the use of GCL with few restrictions on maximum chemical concentrations. The manufacturer does recommend that treated bentonite should be used when directly exposed to liquids with high concentration of salts (divalent cations) such as in seawater (CETCO 2001). The concentration of salts in typical seawater is on the order of 35,000 mg/L (USGS 1989). The ICDF total inorganic leachate concentration is on the order of 17,000 mg/L, approximately 2 times lower than that of seawater. The same compatibility limitation is found in the literature as described in Section 2.1.2. The bentonite added to the soil for the bentonite liner will have the same limitation, however, to a lesser extent since only a small percentage (i.e., 5%) is comprised of bentonite. Based on this assessment, the exposed salts in the brackish leachate will be compatible with the GCL and SBL underlying the geomembrane. Notably, this assumes that the overlying HDPE geomembranes must leak before leachate can come in contact with the GCL or SBL.

### 3. WASTE ACCEPTANCE CRITERIA

#### 3.1 Landfill

Individual constituents in the ICDF landfill design inventory were evaluated to determine maximum allowable ICDF landfill waste concentrations, that if placed in the landfill would generate leachate compatible with the liner system. Many of the individual design inventory constituents have not been included in the composition of leachate used for published compatibility studies. However, the constituents used in the published studies are in similar chemical groups as the constituents in the ICDF design inventory and therefore, would react similarly with the liner materials. Moreover, the use of general chemical categories rather than individual constituents provide a worst-case scenario due to possible synergistic effects of mixed compounds.

Table 3-1 provides the recommended maximum concentration of chemical categories that, if in the landfill leachate, may be incompatible with the polymeric or earthen material comprised of the ICDF landfill and evaporation pond liner systems. These limits are based on review of the published liner compatibility studies and manufacturers' recommendations. The maximum allowable concentration for HDPE geomembrane, GCL, and SBL were compared to determine the highest acceptable value. The lowest of all three values was selected as the suggested maximum concentration. The concentrations based on the design inventory of waste constituents are also provided in Table 3-1. Where available, the recommended maximum allowable concentration with regard to liner compatibility for individual constituents is provided in Tables D-1, D-2, and D-3 in Appendix D for specific organic, inorganic, and radionuclide constituents, respectively.

**Table 3-1. Maximum allowable concentrations in leachate by chemical category.**

Chemical Category	Compatible Concentration for HDPE	Compatible Concentration for GCL and Clay	Suggested ICDF Maximum Concentration or Value	Design Inventory Concentration Dose or Value
Organics	500,000 <sup>a</sup> mg/L	500,000 <sup>b</sup> mg/L	500,000 mg/L	70 mg/L
Acids and Bases	750,000 <sup>a</sup> mg/L	500,000 <sup>b</sup> mg/L	500,000 mg/L	0 <sup>d</sup> mg/L
Inorganic	500,000 <sup>a</sup> mg/L	500,000 <sup>b</sup> mg/L	500,000 mg/L	17,100 mg/L
Dissolved Salts	No Limit	35,000 mg/L	35,000 mg/L	8,000 mg/L <sup>c</sup>
Strong Oxidizers	1,000 mg/L	No limit	1,000 mg/L	0 <sup>d</sup> mg/L
Radionuclides	1,000,000 <sup>b</sup> rads	No limit	1,000,000 rads	12,000 rads (15 yr) 800,000 rads (1000 yr)
pH	0.5 - 13.0 <sup>a</sup>	0.5 - 13.0	0.5 - 13.0	8.0

a. Based on the manufacturers' maximum concentration of the list of constituents tested by the manufacturers. The manufacturers' recommendations are provided in Appendix C.

b. Based on reported literature values.

c. Based on the maximum sodium concentration determined in the Geochemical Evaluation.

d. Strong acids, bases, or oxidizing compounds were not reported in the design inventory.

The concentration and exposure limits in Table 3-1 provide Waste Acceptance Criteria (WAC) for chemical categories. These values can be used as a general guide to determine WAC if individual constituents in the leachate are lower than the limits provided in Appendix D.

The maximum allowable activity concentration of individual radionuclides was determined based on a maximum allowable dose of 1,000,000 rads. The calculated values are provided in Table C-3 in Appendix C. Based on radiation absorbed dose, the mechanical properties of the HDPE liner are not expected to be degraded below acceptable levels.

### **3.2 Evaporation Pond**

The evaporation pond liner system will be comprised of HDPE geomembrane and GCL similar to the landfill liner system underlying a sacrificial geomembrane. The evaporation pond will contain leachate from the landfill and waste liquids from other CERCLA investigations (i.e., well purge water) or remediation tasks. Organics and inorganics in the leachate compatible with the landfill liner will also be compatible with the evaporation pond liner materials since they will be comprised of the same material. Leachate in the evaporation pond from the landfill will also have less concentration of contaminants than when originally in the landfill due to added make-up water, and precipitation.

The maximum allowable concentration of an individual radionuclide and WAC design ratios for the evaporation pond liner is provided in Appendix E. The maximum concentration was developed in the same manner as the landfill maximum allowable concentration assuming a maximum absorption dose of 1,000,000 rads. The allowable concentrations are less than in the landfill due to a greater depth of liquid in the evaporation pond resulting in a higher dose rate.

Waste liquids from other sources in the evaporation pond should not exceed the maximum allowable concentrations of liquids by chemical category in Table 3-1. The recommended maximum allowable concentrations with regard to liner compatibility for individual constituents are provided in Table D-4 of Appendix D.

## 4. CONCLUSIONS

An extensive literature review was performed to evaluate the compatibility of the ICDF landfill and evaporation pond liner materials with the expected leachate composition. Compatibility tests performed at similar sites have shown that HDPE geomembranes can be exposed to high doses of radiation without damage and are compatible with leachate from hazardous waste landfills. Liner manufacturers have also performed compatibility tests using numerous organic and inorganic chemicals, usually in a pure solution, to determine maximum allowable limits. Based on review of literature, the expected leachate concentrations will have no effect on the performance of the ICDF liner system based on the available literature.

The maximum recommended concentration of chemical categories was provided to supply the WACs regarding liner compatibility. General chemical categories rather than individual constituents provide a worst-case scenario due to possible synergistic effects of mixed compounds. However, to provide numerical WAC, individual constituents in the ICDF design inventory were evaluated to determine maximum allowable ICDF landfill waste soil concentrations with regard to liner compatibility. The maximum allowable ICDF landfill waste concentrations are provided in Appendix D.

Samples of 60-mil-thick HDPE geomembrane were irradiated with a total radiation dose of 16,000,000 and 37,000,000 rads for the Hanford Grout facility. The dose rate was 740,000 rads per hour for a total time of 50 hours. These doses showed decreases in the liner's break strength and break elongation due to radiation-induced cross-linking for the polymer chains, decreasing the plasticity of the liner. At the Hanford project W-025 landfill, the HDPE liner showed only a slight reduction in mechanical properties including tensile strength and elasticity after it was irradiated to 50,000 rads for 120 days while submerged in leachate. The literature indicates that the mechanical properties of polymeric materials begin to change at approximately 1,000,000 rads. The geomembrane can accommodate a slight reduction in its strength properties without creating defects that result in leaks since the actual properties are more robust than the design properties (i.e., thickness). Therefore, a maximum radiation dose of 1,000,000 rads for the landfill and evaporation pond liner system during their respective service life is recommended.

The manufacturer for the ICDF geomembrane recommends that leachate have a pH between 0.5 and 13 pH units. Recommended manufacturers' limits for strong oxidizers are 1,000 to 500,000 mg/L and metals, salts, and nutrients of 500,000 mg/L. The permeability of the bentonite used in the GCL and SBL may increase if permeated with leachate having a salt ion concentration. Therefore, a maximum inorganic salt concentration of 35,000 mg/L is recommended as a conservative upper limit. These limits are far above the concentrations expected in the leachate from the ICDF landfill and waste liquids in the evaporation pond. They will be used to determine the maximum allowable concentrations in the waste soil and liquids that if placed in the ICDF landfill or evaporation would not cause significant degradation of the liner system.

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